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**APPLICATION  
FOR  
UNITED STATES  
LETTERS PATENT**

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**FOR: CROSS JOINT**

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## CROSS JOINT

### BACKGROUND OF THE DISCLOSURE

The present invention relates to a cross joint (joint  
5 cross coupling, universal joint) used in a steel rolling mill  
or the like.

In, for example, a steel rolling mill, a cross joint is  
interposed between a roll and a drive shaft for driving to  
10 rotate the roll, a steel rolling processing of the steel  
material can be carried out by rotating to move the roll in  
accordance with rotation of the shaft while the roll is allowed  
to move in an up and down direction relative to a steel material  
which is being rolled. The cross joint includes: a cross shaft  
15 member (cross) having four pieces of shafts arranged in a  
cross-like shape; and a cross bearing which has a plurality  
of cylindrical rollers as rolling members aligned at  
surroundings of the respective shafts of the member, and a  
bearing cup as an outer ring mounted to an outer side of outer  
20 peripheries of the rollers. Each of outer peripheral portions  
of the shafts is used as an inner ring race portion. Further,  
according to the cross joint, the roll and the drive shaft are  
connected to a first shaft and a second shaft comprising  
respective pairs of shafts arranged on straight lines in the  
25 four pieces of the shafts respectively via the cross bearings

and (rotational) torque from the shaft is transmitted to the roll via the cross joint.

Meanwhile, according to the above-described  
5 conventional cross joint, such a cross shaft member and the bearing cup are provided, which are generally constituted by bearing steel of carburized steel or the like.

However, when large torque acts on the cross joint such as in the steel rolling mill, the joint is used under a very  
10 severe condition and there is a concern that even when the bearing steel is used, malfunction is brought about at an early stage. In details, the cylindrical roller is rolled on the inner ring race portion or the like formed at the cross shaft member under high contact surface pressure and therefore,  
15 exfoliation is liable to be brought about at the race portion. Further, according to the cross member, since the roll and the drive shaft are respectively connected to the contiguous pairs of shafts and therefore, large bending stress may be operated to a shoulder portion between shaft root (shaft neck) portions  
20 thereof and fatigue breaking of bending fatigue breaking or the like is liable to be brought about at the member.

#### SUMMARY OF THE INVENTION

In view of the above-described conventional problem, it  
25 is an object of the invention to provide a cross joint capable

of prolonging rolling fatigue life of a rolling portion (life of rolling bearing), capable of increasing a fatigue strength of the cross joint and therefore, capable of achieving long life formation (long fatigue life).

5        In order to solve the aforesaid object, the invention is characterized by having the following arrangement.

(1)    A cross joint comprising:

        a cross shaft member including,

                a four pieces of shafts each having a neck portion

10    and a race portion, and

                shoulder portions provided between adjacent two neck portions;

                rolling members adapted to rotate around the race portions; and

15        outer ring members fitted to the respective shafts via the rolling members,

                wherein the race portions and the shoulder portions are subjected to roller burnishing.

20    (2)    The cross joint according to (1), wherein a race portion formed on the outer ring member is subjected to roller burnishing.

                (3)    The cross joint according to (1), wherein a residual  
25    compressive stress at a depth of at least 0.3mm from each of

surfaces of the race portions and the shoulder portion subjected to the roller burnishing is made to be equal to or larger than 800 MPa.

5 (4) The cross joint according to (1), wherein the cross shaft member and the outer ring member includes a carbon steel for a mechanical structure having a carbon content equal to or larger than 0.42 weight %.

10 (5) A method of manufacturing a cross joint which includes: a cross shaft member including, a four pieces of shafts each having a neck portion and a race portion, and shoulder portions provided between adjacent two neck portions; rolling members adapted to rotate around the race portions; and outer ring  
15 members fitted to the respective shafts via the rolling members, the method comprising the step of subjecting the race portions and the shoulder portions to roller burnishing.

(6) The method according to (5) further comprising the step  
20 of subjecting a race portion formed on the outer ring member to roller burnishing.

According to the above-described cross joint, by subjecting the race portion and the shoulder portion of the  
25 cross shaft member to roller burnishing, the hardness of each

of surfaces of the race portion and the shoulder portion can be increased and a residual compressive stress immediately below the surface can be increased. Further, a roughness of each of the surfaces can also be decreased.

5        According to the cross joint, the hardness of the surface of the race portion of the outer ring member can be increased and the residual compressive stress immediately below the surface can also be increased. Further, the roughness of the surface can also be decreased.

10        According to the cross joint, in comparison with the above-described conventional product, the fatigue strength of the race portion and the shoulder portion can further effectively be increased.

15        According to the cross joint, the fatigue strength substantially comparable to that of the conventional bearing steel can be achieved.

20        BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an outline sectional view showing an essential portion of a cross joint according to an embodiment of the invention.

Fig. 2 is a graph diagram showing a result of measuring  
25    a hardness at each depth from a surface of a race portion.

Fig. 3 is a graph diagram showing a result of measuring a residual compressive stress at each depth from the surface of the race portion.

5            DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A preferable embodiment showing a cross joint of the invention will be explained in reference to the drawings as follows. Further, in the following explanation, an explanation will be given of a case of applying the invention  
10 to a cross joint for driving a roll integrated into a steel rolling mill.

Fig. 1 is an outline sectional view showing an essential portion of a cross joint according to an embodiment of the invention. In the drawing, a cross joint 1 according to the  
15 embodiment is provided with a cross shaft member 2 integrally constituted with a base portion 2a and four pieces of shafts 2b arranged to project from the base portion 2a in a cross-like shape, and roller bearings 5 each having a bearing cup 4 as an outer ring member outwardly fitted to an outer side of an  
20 outer periphery of each of the shafts 2b via cylindrical rollers 3.

The outer peripheral portions of the respective shafts 2b of the cross shaft member 2 are formed with inner ring race  
25 portions 2c with which the cylindrical rollers 3 are brought

into rolling contact and the respective shafts 2b of the member 2 are made to function as inner ring members of corresponding ones of the roller bearings 5. The base portion 2a of the cross shaft member 2 is provided with shoulder portions 2d each having  
5 a section in a round-shape in which a center of a radius of curvature is set to an outer side of the base portion 2a and a center portion thereof is recessed to a side of a center portion of the base portion 2a, at respective intervals between  
10 necks (shaft necks) of twos of the shafts 2b contiguous to each other. An inside of the roller bearing 5 is constituted to be able to be hermetically sealed by attaching a seal member in a ring-like shape (not illustrated) to the shoulder portion 2d.

15 The bearing cup 4 is provided with an outer ring race portion 4a and the cylindrical rollers 3 are rolled at inside of the cup 4. Further, the bearing cups 4 are attached to the roll or the drive shaft such that the roll of the steel rolling mill and the drive shaft are respectively connected to  
20 horizontal shafts and vertical shafts of the cross shafts comprising two pairs of the shafts 2b respectively aligned linearly (not illustrated). Rotation of the shaft is transmitted to the roll to rotate it in a state that the cross joint permits the roll to rock relative to the shaft axis.  
25 Further, the bearing cup 4 is provided with a grease nipple



(not illustrated) and grease can pertinently be supplied to portions of the cylindrical rollers 3 rolling on the respective race portions 2c and 4a.

Further, other than the above-described explanation, in place of the cylindrical roller 3, a needle-shape needle roller can also be used as a rolling member rolling between the respective race portions 2c and 4a.

The cross shaft member 2 and the bearing cup 4 are constituted by using bearing steel of SUJ2 2 or the like or a steel material which is carburized or carbonitride by subjecting the material steel to high-frequency quenching or the like. Further, the race portion 2c and the shoulder portion 2d of the cross shaft member 2 and the race portion 4a of the bearing cup 4 are finished to predetermined accuracy by being subjected to finishing by cutting, machining, grinding or polishing.

Further, the race portions 2c and 4a and the shoulder portion 2d are subjected to roller burnishing (deep rolling) after the finishing. According to the roller burnishing, while a mirror finish ball (mirror finished surface ball) made of ceramics held by, for example, hydraulic pressure is pressed to a surface of a working portion of the race portion 2c of the like to bring into rolling contact therewith by strong pressure, the mirror finish ball is moved on the surface of

the working portion. According to the roller burnishing, working conditions of an amount of burnishing, press force and the like are selected such that, for example, hardness at a depth of at least 0.2mm from the surface of the working portion is work-hardened to be equal to or larger than Hv700 and a residual compressive stress at a depth of at least 0.3mm from the surface of the working portion becomes equal to or larger than 800 MPa.

Here, a specific explanation will be given of operation and effect of the roller burnishing in reference to Fig. 2 and Fig. 3 showing an example of a result of a verifying test which has been carried out by the inventors and the like of the invention. Further, in the following explanation, an explanation will be given by exemplifying a verified result at the race portion 2c on the side of the cross shaft member 2 and a mention will also be given of a measured result of a material only subjected to a carburizing treatment before roller burnishing and a material subjected to shot peening in addition to the carburizing treatment for comparison.

As has been apparent from Fig. 2, each race portion 2c after roller burnishing is ensured with a hardness equal to or larger than Hv700 at a depth of at least 0.2mm from the surface and is considerably harder than a product before roller

burnishing and a shot-peened product. Further, at a depth less than 0.1mm from surface, a surface hardness of the shot-peened product is more or less harder than that of each race portion 2c, the shot-peened product is deteriorated in the surface roughness after working (the surface is roughened) and needs postworking for smoothing the surface for making the cylindrical roller 3 roll in an oil-lubricated state. Specifically, according to the shot-peened product, it is necessary to remove a surface layer thereof at a depth of about 0.05mm from the surface by the postworking.

In contrast thereto, according to each race portion 2c, since the surface is pressed by point contact with the mirror finish ball in roller burnishing, the surface hardness can be hardened while improving (reducing) the surface roughness by smoothly deforming the surface, and contrary to the shot-peened product, it is not necessary to subject the surface to postworking. Therefore, the surface hardness of each race portion 2c is substantially harder than that of the shot-peened product. Further, according to a test by the inventor of the application, it has been confirmed that the surface roughness of each race portion 2c by roller burnishing can be made to be equal to or less than a half of that before working in a maximum height roughness ( $R_{max}$ ) and a surface hardening coefficient can be increased compared with that before working.

In this way, the fatigue strength of the race portion 2c can be increased by improving the surface hardening coefficient of the race portion 2c and increasing the surface hardness and surface originated flaking (surface layer flaking) at the race  
5 portion 2c can effectively be restrained from being brought about.

Further, as shown in Fig. 3, at each race portion 2c, a residual compressive stress equal to or larger than 800MPa  
10 is generated at a depth of at least 0.3mm from the surface and work hardening is produced up to a depth about twice as much as that of the short-peened product. By producing the large residual compressive stress at the race portion 2c in this way, inner portion originated flaking at the race portion 2c can  
15 effectively be restrained from being brought about and the fatigue strength against stresses generated at inside of the race portion 2c can be increased. That is, at the shoulder portion 2d subjected to roller burnishing, the fatigue strength against bending stress operated by two of the shafts  
20 2b continuous to the shoulder portion 2d can be increased and the bending fatigue breaking (fracture) can effectively be restrained from being brought about.

As described above, according to the cross joint 1  
25 according to the embodiment, by subjecting the race portions

2c and 4a provided at the cross shaft member 2 and the bearing cup (outer ring member) 4 and the shoulder portion 2d of the cross shaft member 2 to roller burnishing, while improving roughnesses of the respective surfaces of the race portions 2c and 4a and the shoulder portion 2d, the surface harnesses can be increased and the residual compressive stresses immediately below the surfaces can be increased. As a result, in comparison with the conventional product which is not subjected to roller burnishing, exfoliation life of the race portions 2c and 4a can be prolonged and the fatigue strength of the race portions 2c and 4a and the shoulder portion 2d can be increased and therefore, long life formation of the cross joint 1 can be achieved. Further, since the cross joint 1 is provided with the race portions 2c and 4a having long flaking life (life of rolling bearing) and provided with the cross shaft member 2 and the bearing cup 4 having excellent fatigue strength, a cross joint used under a very severe condition by being integrated to a transmitting mechanism for transmitting high torque from a drive shaft to a driven shaft can simply be constituted.

Further, according to the embodiment, the residual compressive stress at the depth of at least 0.3mm from the respective surfaces of the race portions 2c and 4a and the shoulder portion 2d is made to be equal to or larger than 800MPa

and therefore, in comparison with the above-described conventional product, the fatigue strength of the race portions 2c and 4a and the shoulder portion 4d can effectively be increased.

5

Further, although according to the above-described explanation, an explanation has been given of a case of applying to the cross joint integrated into the steel rolling mill, the invention is not limited thereto but is applicable to various kinds of cross joints (universal joints) connected to, for example, a propeller shaft of an automobile and the like.

Further, although according to the above-described explanation, an explanation has been given of the constitution in which the center of the radius of curvature is set on the outer side of the base portion 2a and the shoulder portion 2a having the section in the round-shape in which the central portion is recessed to the side of the center portion of the base portion 2a is subjected to roller burnishing, according to the invention, each shoulder portion between two of the shaft neck portions of the cross shaft member (cross or spider) phases of which are shifted from each other by 90 degrees may be subjected to roller burnishing and the shape of the shoulder portion is not limited to the above-described at all.

Specifically, there may be constructed a constitution in which a shoulder portion having a section in a linear shape or a

shoulder portion having a section in a round shape in which the center of a radius of curvature is set to a center side portion of a base portion such that a central portion thereof bulges to an outer side of the base portion is subjected to  
5 roller burnishing.

Further, although according to the above-described explanation, an explanation has been given of a case of constituting the cross shaft member 2 and the bearing cup 4  
10 by using bearing steel, the invention is not limited thereto but there may be constructed a constitution in which a cross shaft member or the like is constituted by carbon steel for mechanical structure of S54C or S55C or the like having a carbon content of, for example, 0.42 weight % or more, or a steel  
15 material hardened to a hardness of about HRC55 by subjecting the material steel to a heat treatment or a high-frequency quenching treatment and the race portion and the shoulder portion is subjected to roller burnishing. By using carbon steel for mechanical structure in this way, a cross shaft member  
20 having a fatigue strength substantially comparable to that of the conventional product comprising bearing steel and restraining material cost can easily be constituted and the cross joint can be fabricated at low cost.

25 The invention constituted as described above achieves

the following effects.

According to the cross joint of the invention, by  
subjecting the race portion and the shoulder portion of the  
cross shaft member to roller burnishing, the hardness of each  
5 of the surfaces of the race portion and the shoulder portion  
is increased and the residual compressive stress immediately  
before the surface is increased and therefore, in addition to  
that the roughness of each of the surfaces can be decreased,  
in comparison with the conventional product which is not  
10 subjected to roller burnishing, exfoliation life of the race  
portion can be prolonged, the fatigue strength of the cross  
shaft member can effectively be increased and therefore, long  
life formation of the cross joint can be achieved.

15 Further, according to the cross joint of the invention,  
by subjecting the race portion of the outer ring member to  
roller burnishing, the hardness of the surface of the race  
portion is increased, the residual compressive stress  
immediately below the surface is increased and therefore, in  
20 addition to that the roughness of the surface can be increased,  
in comparison with the conventional product which is not  
subjected to roller burnishing, the exfoliation life of the  
race portion can be prolonged.

25 Further, according to the cross joint of the invention,



in comparison with the conventional product, the fatigue strength of the race portion and the shoulder portion can further effectively be increased and long life formation of the cross joint can further effectively be achieved.

5           Further, according to the cross joint of the invention, the life substantially comparable to that of the cross joint comprising bearing steel can be ensured by an inexpensive material.

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